Conductivity Measurement of Conductive Materials Using Line Resonator Method

(Design and performance comparison of conductive textile-based UWB antenna and conductive ink-based UWB antenna on PET substrate)

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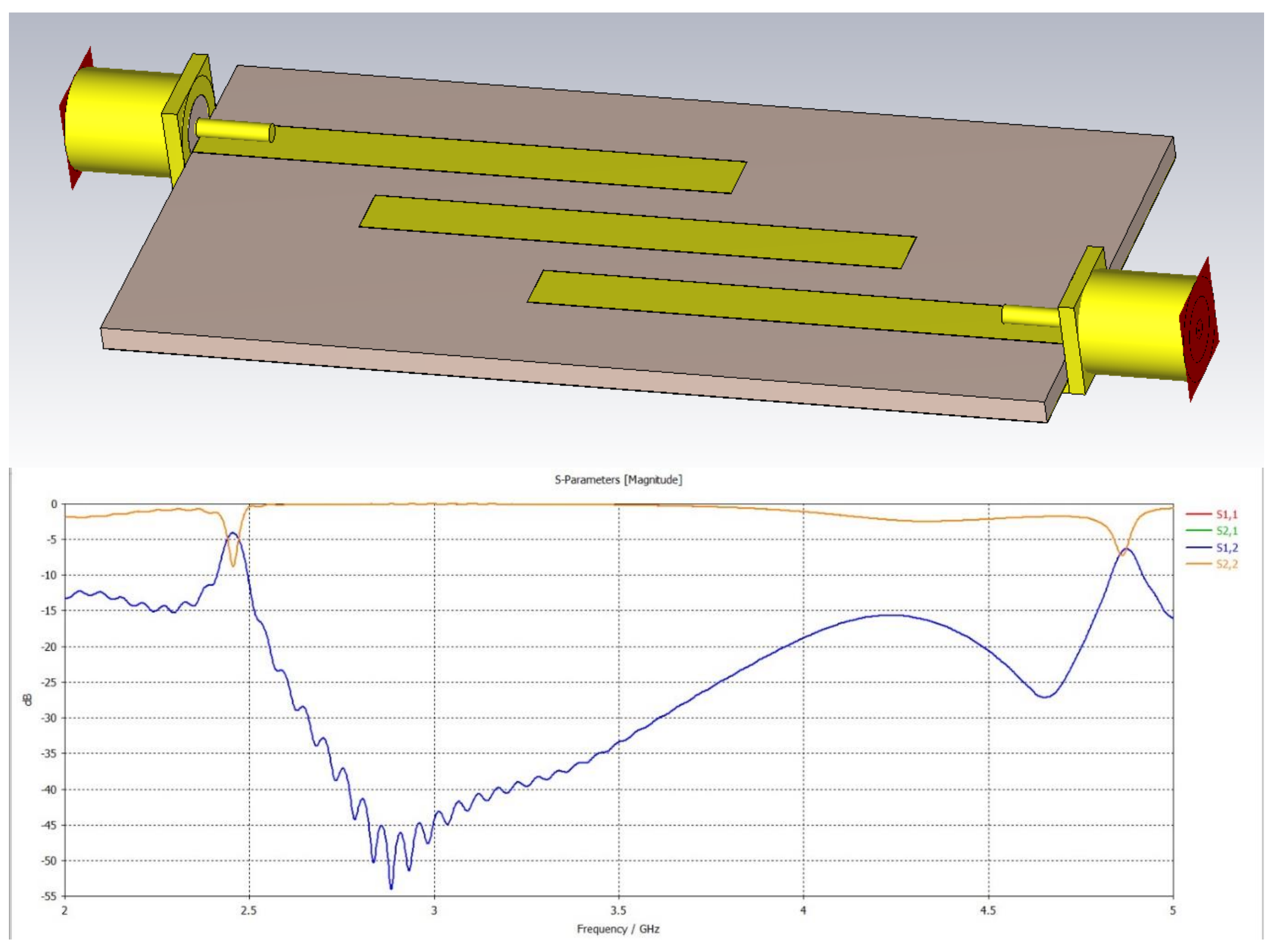
Introduction

The development of flexible conductive materials is becoming increasingly demanding in antennas due to their vast variety of applications in healthcare, telemedicine, medical microwave radiometers, and the Internet of Things (IoT). However, ac conductive properties of metalized textiles are not known which hinders their practical implication in realizing flexible antenna for biomedical applications. Therefore, in this project, the conductivity of various samples shall be determined using a line resonator.

Solution Methodology

The resonant method exploits the resonance behavior of an electromagnetic circuit. This technique is more suitable when accurate information of electromagnetic properties is required at a specific frequency.



The final model and the results of the line resonator that designed in the CST Studio Suite

To measure the conductivity of the material we want to test, first we need to measure the copper lines and then replace the middle line of the resonator with the material to measure the new S-parameters. By using S-parameters and the losses we can get close results. To calculate we can use this method:

$$\varepsilon_r^{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\frac{h}{w}}}\right)$$

Since in our case $\frac{w}{h} \geq 1$ the characteristic impedance formula becomes

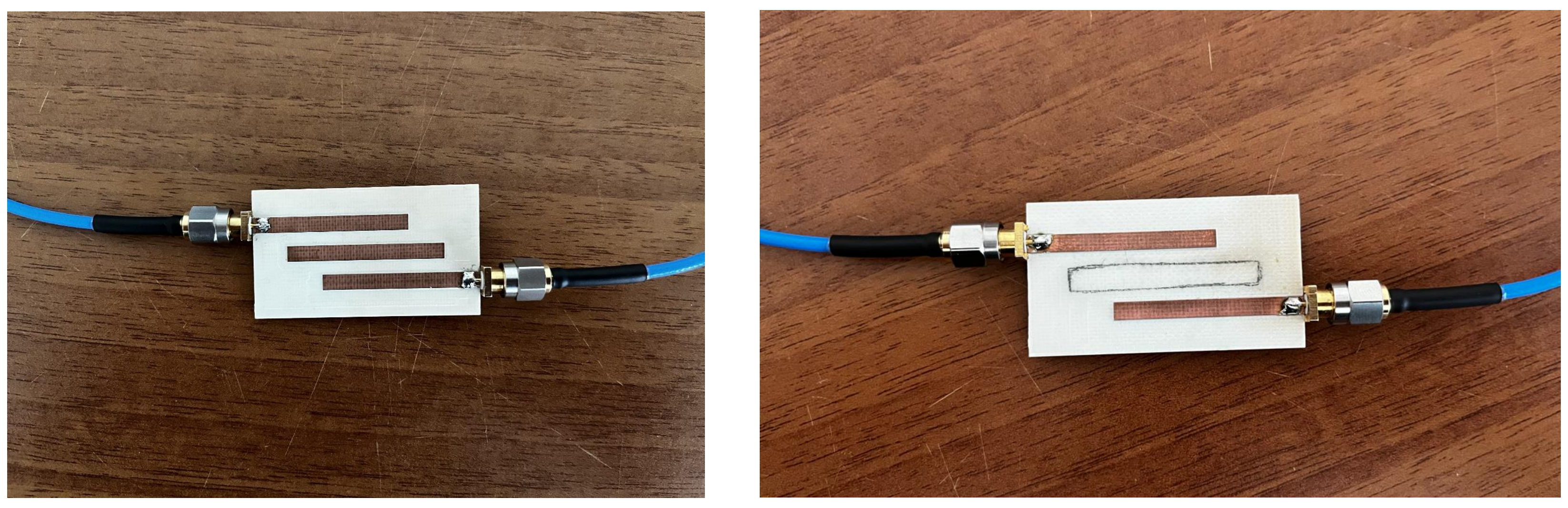
$$Z_0 = \frac{\eta_0}{\sqrt{\varepsilon_r^{eff}}\left(\frac{W}{h} + 1.393 + 0.667\, ln\left(\frac{W}{h} + 1{,}444\right)\right)}$$

$$\alpha_d = \frac{k_0\sqrt{\varepsilon_r}}{2}\, tan\,\delta \left[\sqrt{\frac{\varepsilon_r}{\varepsilon_r^{eff}}}\,\frac{(\varepsilon_r^{eff} - 1)}{(\varepsilon_r - 1)}\right]$$

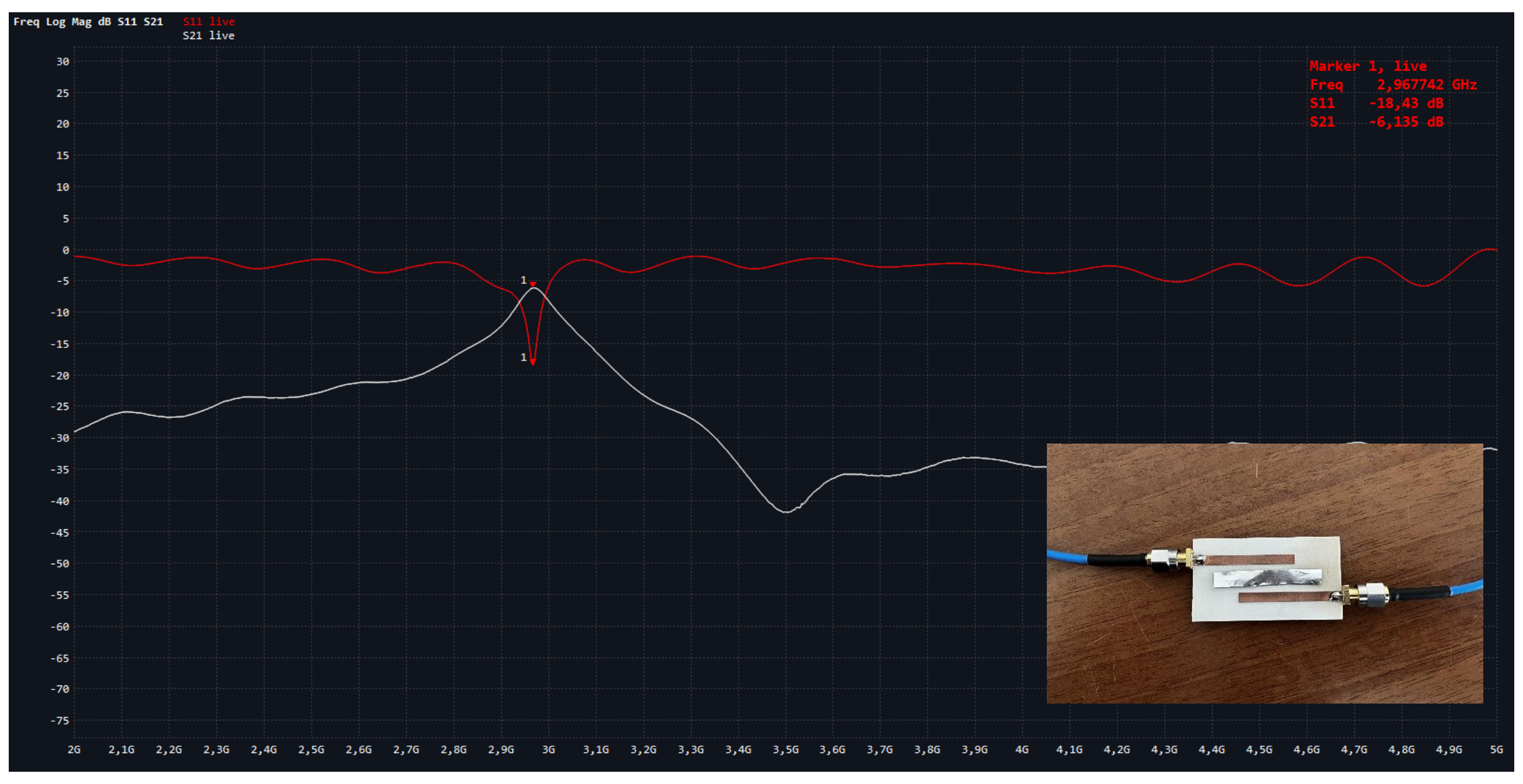
$$k_0 = \frac{2\pi f}{c} \text{ and } tan\,\delta \cong 0.0021$$

Now by using $Q = \frac{\beta}{2\alpha} = \frac{k_0 \times \sqrt{\varepsilon_r^e}}{2(\alpha_c + \alpha_d)} = \frac{f}{\Delta f}$ and $\alpha_C = \frac{R_s}{Z_0 w}$, we can find surface resistivity(R_s) of the material and calculate the conductivity using $\sigma = \frac{2\pi f \mu}{2R_s^2}$.

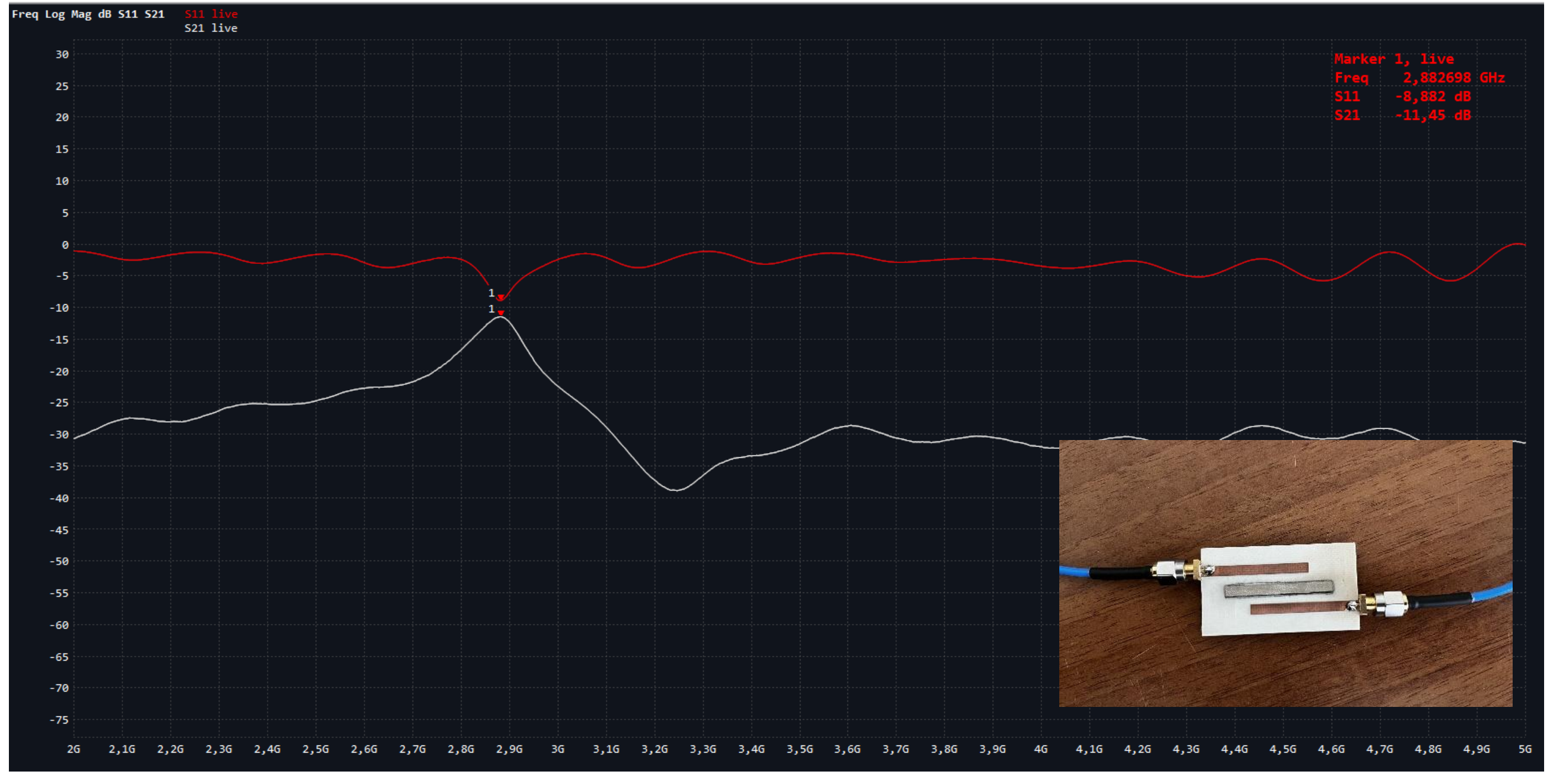
Results and Discussion



Original resonator and test resonator



S-parameter results of the resonator that middle line was replaced with aluminum foil



S-parameter results of the resonator that middle line was replaced with conductive textile

Material	Calculated Value	Real Value
Copper	6.3×10^7	5.96×10^7
Aluminium Foil	2.8×10^7	3.5×10^7
Textile	8.2×10^5	Unknown

Test results and real values are close with little difference due to non-ideal measuring conditions and calculation errors.

References

- D. Pozar, Microwave Engineering, 3rd ed. Hoboken, New Jersey: John Wiley & Sons Inc., 2005.

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